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VICKSBURG MOBILITY EXERCISE A: DESIGN OF FIELD TEST PROGRAM; REPORT OF MEETING (2ND) HELD AT VICKSBURG, MISSISSIPPI ON 8-10 FEBRUARY 1967

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

March 1968

MISCELLANEOUS PAPER NO. 4-979

REPORT OF SECOND MEETING VICKSBURG MOBILITY EXERCISE A DESIGN OF FIELD TEST PROGRAM

(8 - 10 FEBRUARY 1967, VICKSBURG, MISSISSIPPI)

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Sponsored by

U. S. Army Materiel Command

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ARMY-MRC VICKSBURG, MISS.

Foreword

As a result of instructions from GEN Frank S. Besson, Jr., Commanding General, U. S. Army Materiel Command (AMC), that steps be taken to present a research program covering the total mobility problem involved in development of vehicle concepts for remote-area operation on low strength soil, a group of mobility, soil, and terrain evaluation specialists of AMC and the U. S. Army Corps of Engineers, together with associated consultants, met at the U. S. Army Engineer Waterways Experiment Station (WES) during the period 21-25 September 1964 to conduct such a study. The results of this study were presented in Miscellaneous Paper No. 4-702 entitled "Vicksburg Mobility Exercise A: Vehicle Analysis for Remote-Area Operation."

After the test beds proposed in the above-mentioned study were fabricated and delivered, a second meeting of the group was held at the WES during the period 8-10 February 1967 to design and implement an agreed-upon field program for testing the three vehicle test beds. The results of this meeting, together with a list of attendees, are reported herein.

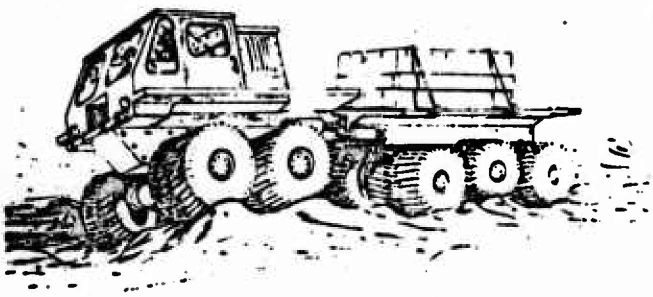
The draft of this report was prepared by the members of the three working groups on loading equality, site selection, and test procedures under the general directions of Messrs. W. G. Shockley and S. J. Knight, Chief and Assistant Chief, respectively, of the Mobility and Environmental Division, and under the direct supervision of Mr. A. A. Rula, Chief, Vehicle Studies Branch. Mr. Rula was responsible for preparation of the final report.

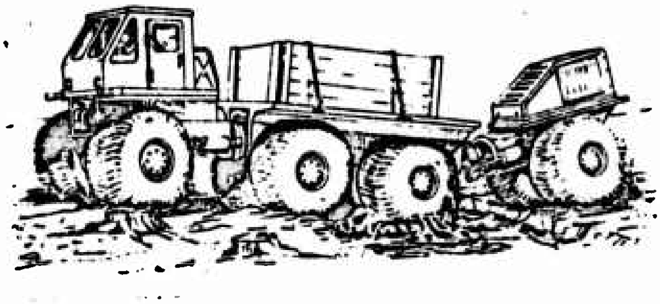
COL John R. Oswalt, Jr., was Director of WES at the time of the second meeting and during the preparation of this report. Mr. J. B. Tiffany was Technical Director.

REPORT OF SECOND MEETING
VICKSBURG MOBILITY EXERCISE A

DESIGN OF FIELD TEST PROGRAM

(8-10 February 1967, Vicksburg, Mississippi)





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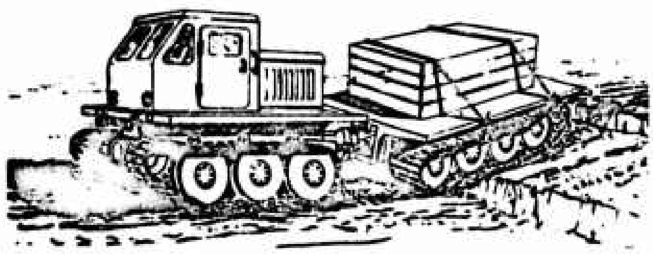

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
Vicksburg, Mississippi

REPORT OF SECOND MEETING
VICKSBURG MOBILITY EXERCISE A
DESIGN OF FIELD TEST PROGRAM
(8-10 February 1967, Vicksburg, Mississippi)

Introduction

1. It has been proposed that mobility can be considered as rate of transport of materiel. In terms of payload delivered, this can be expressed in ton-miles per hour. In remote areas of the world, and more particularly in those areas where soft soils abound, movement of a vehicle may be impaired seriously even though the vehicle may not be bogged down. Where solid footing is present, obstructions may lengthen paths of travel or surface microroughness may limit vehicle speeds. On road, such factors as tires, tracks, suspensions, power, et al. can produce varied results in mobility.

2. One may accept the fact that a ground vehicle can be built to traverse extremely soft soils. Such a vehicle, however, becomes so encumbered with flotation and traction devices that its payload capacity is seriously limited. On road, such a vehicle has too little value in competing with road-bound designs.

3. It is known that vehicle performance characteristics can be brought into balance with penalties induced by the character of the terrain when necessary by making preparations such as roads. It is postulated that discernible laws tie these factors of performance, penalties, and preparation into a mobility equation whereby the influence of any of these three can be analyzed in terms of mobility to be achieved.

4. Motivated by this reasoning, General F. S. Besson, Jr., Commanding General, U. S. Army Materiel Command, directed that experiments be conducted to detect the nature of these laws. In the period 21-25 September 1964, a group of experts met at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, for the purpose of designing such an experiment. During this period of intensive study, significant remote areas were selected and described, vehicle concepts (test beds) suited to the experiment were designed, and a test program to accomplish the experiment was outlined (see Miscellaneous Paper No. 4-702, "Vicksburg Mobility Exercise A, Vehicle Analysis for Remote-Area Operations," February 1965).

5. Three test beds were proposed by this study, all 2-1/2-ton carriers, two mounted on Terra tires and one on tracks. Of the two vehicles with tires, one (10x10) has a two-unit articulated configuration and the other (8x8) a three-unit articulated configuration. The tracked vehicle has a two-unit articulated configuration. In the course of Vicksburg Mobility Exercise A (hereinafter referred to as VEXA) it was agreed to place these test beds in competition with three standard military vehicles, namely, the M135, the XM410, and the M113, and to do so on courses (about five) on soils ranging from very soft to hard and on a paved surface, measuring some conventional vehicle characteristics but focusing upon the mobility (ton-miles per hour) performance parameters over these courses.

6. The three test beds have been fabricated and delivered to the contracting officer of the U. S. Army Tank-Automotive Command (ATAC) at Houghton, Michigan.

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7. A second meeting of a group of mobility, soil, and terrain evaluation specialists of the U. S. Army Materiel Command (AMC) and the U. S. Army Corps of Engineers, together with associated consultants, was held at WES 8-10 February 1967 to design and implement an agreed-upon field program for testing the three vehicle test beds. A list of attendees is given in Incl 1. The meeting agenda is presented in Incl 2.

Meeting Proceedings

8. Mr. Philippe opened the meeting by stating that its purpose was to design experiments for field testing the AMC test beds. He said that costs for the field-testing program estimated at the first meeting of Vicksburg Exercise A were used in programming funds. FY 67 funds in the amount of $500,000 will be allocated on 15 February 1967; the amount is not to be exceeded.

9. A request was made for a restatement of the original purpose of Vicksburg Exercise A. Mr. Philippe emphasized that the intent is not to test vehicles per se but to test a new mobility concept using rate of delivery in terms of ton-miles per hour as a performance parameter. The test program should first provide sufficient data to permit the development of relations which show the effect of soil strength, including pavement, on rate of transport over level surfaces. The program should also provide for testing the vehicles on courses which will include slopes, obstacles, etc., so as to permit the evaluation of analytical models for predicting transportability. Mr. Philippe's first testing requirement is illustrated

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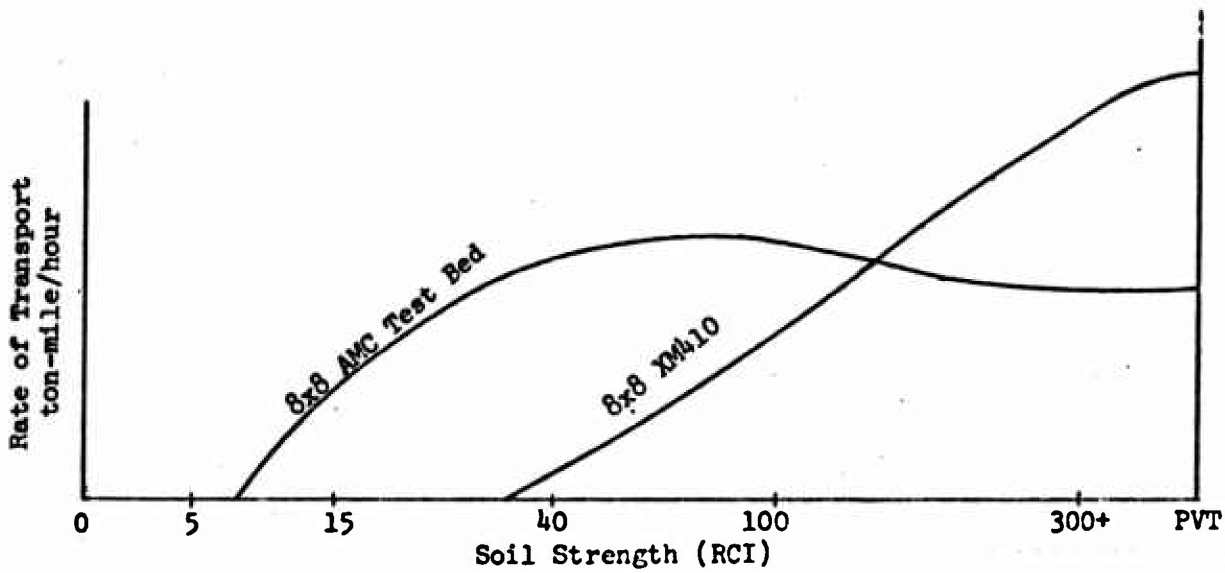
in the following diagram. The effects of other terrain factors can also be evaluated by similar relations.



Mr. Philippe pointed out that the illustration indicates the penalty that one pays while operating on surfaces having different strengths. The AMC test beds will begin to operate in much softer soil conditions than do current military vehicles; however, their rate of transport will probably not continue to increase (and may even decrease) beyond a certain soil strength. The more conventional vehicles, on the other hand, require a higher soil strength to begin operation, but with increase in soil strength, their transport capability will reach and ultimately exceed that of the less conventional vehicles.

10. Mr. Philippe also requested that in the test plans there be included a very modest preliminary test program which would at least provide crude information as to which of the AMC test beds may provide the best soft-soil performance and a relative evaluation as to how much better the performance is when compared to that of the M113 tracked personnel carrier.

11. Mr. Shockley presented a résumé of the results of the first VEXA meeting held at WES in September 1964. He stated that in deliberations of measures of off-road effectiveness, several fundamental realizations had emerged which were used in establishing the framework for the exercise, as follows:

a. No single vehicle can be conceived that will provide effective mobility in all ranges of ground conditions from the softest soils to the highway.

b. A vehicle designed to meet a given set of ground conditions will suffer penalties when operating on another set of conditions.

c. The Army should have the minimum number of sets of vehicles to meet all operating problems.

d. This apparent dilemma is met in civil life by full preparation of roads, highways, railroads, and airfields. Various degrees of preparation are also utilized in military operations.

12. The general purpose of the first VEXA meeting was to consider quantitatively the various elements of the entire mobility problem and to suggest an approach to achieve at least a substantial degree of solution. The principal specific purpose was to design a number of vehicle test bed concepts that would operate in remote areas of the world where extreme soft-soil conditions predominate and to develop a test program for these vehicles. To achieve the purpose it was necessary to consider soil characteristics, design of vehicle concepts, and testing.

13. The participants in VEXA established the requirements for three test beds, an 8x8 wheeled concept, a 10x10 wheeled concept, and a tracked concept, and designed tests to evaluate the test beds.

14. Two test programs were designed, a basic program which would establish whether or not the test beds met the design requirements, and a supplemental test program which would include terrain factors in addition to soil strength in such a manner that terrain-vehicle relations could be developed in accordance with a first-generation analytical model for predicting the speed performance of vehicles operating in the off-road environment.

15. Mr. Rogers, of Clark Equipment Co., which built the AMC test beds, presented information on their design, fabrication, and status. The minimum vehicle weights specified in the contract were exceeded because so much weight is in the standard power train components. About 20 percent (2500 lb) of the vehicle weight is used in providing the necessary structural requirements and 80 percent of the vehicle weight is in the engine, drive-train, and traction elements, which are commercial items with substantially fixed weights. After it was apparent that steel would greatly exceed the weight limitations, the structural elements of the vehicles were redesigned using aluminum. The tire rims presented a problem, and special rims had to be built. Because of the nonavailability of the 53x37 tire specified for the 8x8 vehicle, a 48x31 tire was substituted. The power is provided by Chrysler industrial gasoline engines. Weight was reduced by using the lightest gears possible; tire tread was reduced to a minimum; and a light-weight cab was fabricated. The frame structure is box type. The load deck consists of expanded metal, and it will not support concentrated loads. The hydraulic control system on the 8x8 test bed presented some problems because of the length of hydraulic lines and operation at low temperatures.

Temperature compensators have been adapted to keep the hydraulic system operational in cold weather. The hydraulic system is similar on all three vehicles. The vehicles are somewhat difficult to service because so much "plumbing" is built around the engines. To obtain maximum performance, trained operators are required since there is a sequence that must be followed to obtain proper performance. Clark Equipment Co. will service the test beds for the next 12 months, and as experience is gained, will recommend changes should they be necessary to facilitate servicing of the vehicles. The vehicles have been shipped to Houghton, Michigan, for shakedown tests to be completed by 26 February 1967.

16. Mr. Rogers presented a 16-mm movie film and slides of the operation of the test beds over a 30-in.-high obstacle and several snow-covered fields. He said that the ability of the vehicles to negotiate 30-in.-high obstacles was dependent upon the skill of the driver. No difference in vehicle performance was noted in their operational runs except that the tracked vehicle could not negotiate steep slopes covered with snow or soft mud.

17. Several questions were asked pertaining to vehicle characteristics and development. Pertinent questions and answers are presented below.

a. What is the vehicle speed? -- The engines are governed at 3000 rpm. At 3000 rpm the 8x8 will travel 28 mph on a hard, level surface. The governors can be adjusted to permit a top speed of 40 mph. Surface roughness will probably be the primary factor controlling speed on firm surfaces.

b. What is the turning radius? -- A crude test was made and the turning radius of the 8x8 is about 30 ft.

c. Is information available on wheel loads? -- No, only the vehicle weight, including fuel and lubricants (wet weight), as follows: 8x8, 14,200 lb; 10x10, 12,400 lb; tracked, 14,200 lb.

d. Could the weights of the vehicles be reduced substantially if funds were available to make a wholesale attack on reducing the weights of component parts? -- It is possible but not practical. The cost would be fantastic because of the exotic theoretical studies and components required.

e. What is the test bed payload? -- Payload for all test beds is 5,000 lb.

18. Mr. Rula presented a basic test plan prepared by WES for testing the AMC test beds and three conventional military vehicles for comparative evaluation. His presentation included the purpose, scope, vehicles to be tested, types of tests to be conducted, test lane requirements for soil and obstacle tests, location and selection of test areas, and an outline of specific-test plans, including program costs. The soil strength ranges required for the vehicles to be tested and the type of tests to be conducted are summarized in table 1; location and description of suggested test areas are given in table 2; and an outline for the proposed basic test plan is given in table 3. Mr. Rula stated the purpose of the basic and supplemental test programs. The purpose of the basic test program is to evaluate the methods of design employed to specify characteristics of wheeled and tracked vehicle traction components that would yield the desired soft-soil and obstacle performance, and to compare the performance of the test beds

with that of approximately comparable conventional military vehicles on smooth, level surfaces. The purpose of the supplemental test program is to develop pertinent vehicle-terrain relations as required in the application of the analytical model for predicting vehicle performance in terms of speed.

19. Mr. Stinson presented a supplemental test plan proposed by WES for testing the AMC test beds and three conventional military vehicles. He stated that an expression for total mobility in the form of an analytical model for predicting cross-country vehicle performance is available and that substantial progress has been made since the first VEXA meeting and an operational first generation computer model is now available. The types of tests required to develop soil, obstacle-vehicle relations required as model inputs were presented and each was discussed in terms of purpose, scope, test site requirements, data to be collected, test procedures, and cost. Included were acceleration-rolling and acceleration-braking tests, determinati~~on of~~ maneuver-soil strength relations, effects of wet-surface soil condition on traction performance, maximum traction performance evaluation tests on hard surface, performance evaluation tests on vertical obstacles, and performance evaluation tests in lateral obstacles. An outline for the WES supplemental test plan is given in table 4.

20. Following the presentation of the basic and supplemental test plans proposed by WES, Mr. Philippe asked for discussion on the concepts and philosophy underlying the test plans. He initiated the discussion by stating that he had no feel for the correlation between the two test plans. Most of

the discussion which followed was focused on the merits and demerits of model testing including procedures and input requirements. For clarification the purpose of the test plans was restated. Briefly, the basic program was designed to evaluate the performance of the test beds in soft terrains and to compare the performance of the test beds with that of approximately comparable conventional military vehicles. These tests would also furnish starting points for the relations sought in the supplemental test program. The supplemental program would furnish empirical relations by which to compare the test beds and conventional vehicles throughout a range of soil and obstacle conditions. Also the supplemental program would provide input to the model from which a mobility prediction in terms of speed could be made for point A to B. Proof tests would be used for model verification.

21. Mr. Philippe stated that the principal objective of the test program should be to develop the information from which to compute the penalty paid (in terms of ton-miles per hour) to get performance on soft soil, and he asked that the discussion be focused on structuring a test program with which the participants could agree. Following the discussion, a four-phase program was outlined by Mr. Philippe in addition to the preliminary test program described in paragraph 10. The four-phase program in order of priority was identified as follows:

Phase I: Establish the relations between soil strength and cargo delivery (in ton-miles/hour) for the entire spectrum of soil strengths, from the immobilization point of each test bed (3) and military vehicle (3) to a hard-surface road. An essential condition is that no terrain factors other than soil strength be considered.

Phase II: Establish the engineering performance characteristics of the test beds and military test vehicles, in conjunction with Phase I over the full strength range of soils,and determine essential terrain-vehicle relations, including acceleration and deceleration, maneuverability, drawbar pull-slip-strength relations, motion resistance, and VCI.

Phase III: Refine or improve those terrain-vehicle relations which can be predicted or described with the least reliability by the existing cross-country speed performance model, with special emphasis on the dynamic response of the machines to vertical obstacles (i.e. ground roughness), and soil slipperiness-traction relations. An ancillary objective is to update the cross-country speed prediction model.

Phase IV: Test the capability of the updated cross-country speed prediction model to reliably predict the cross-country speed performance of the test beds and military test vehicles. This phase will incorporate an evaluation of the possible degradation of prediction accuracy as a result of terrain input derived by air-photo interpretation as opposed to field measurement of appropriate terrain parameters.

22. The WES, AMC, and U. S. Army Corps of Engineers personnel and the consultants were assigned to four working groups on 8 February to consider the important elements of the testing program and develop the necessary guidelines from which detailed test plans could be prepared at a later date. These groups were as follows:

a. Executive. This group, charged with coordinating the activities of the other working groups, was composed of Messrs. R. R. Philippe (Chairman), W. G. Shockley, and R. C. Kerr.

b. Loading equality. This group was assigned the responsibility for considering the inequalities of empty weight among the test beds and the military test vehicles and to recommend loading procedures which would be conducive to comparative analysis at the completion of the tests. It was composed of Messrs. R. A. Liston (Chairman), Bruce Rogers, A. J. Green, and W. P. Gregory.

c. Site selection. This group was assigned the responsibility for recommending actual test sites selected to give the range of soil strength values desired in the experiment and for designating time of accessibility (including weather and season considerations) and other related factors having influence on the testing schedule. This group was composed of Messrs. S. J. Knight (Chairman), E. S. Rush, J. L. Smith, B. O. Benn, and M. V. Kreipke.

d. Test procedures. The responsibility of this group was to establish test procedures compatible with site selection in sufficient detail to provide guidance to both WES and Land Locomotion Laboratory (LLL) to proceed with planning the test program in intimate detail. This group was composed of Messrs. A. A. Rula (Chairman), B. G. Stinson, W. E. Grabau, R. G. Ahlvin, P. F. Carlton, J. P. Sale, C. J. Nuttall, Jr., and B. G. Schreiner, and Dr. D. R. Freitag.

23. The working groups reconvened on 10 February to report on the results of their deliberations and to integrate the results. Each working group chairman presented a brief summary of his group's efforts as follows:

a. Loading equality. Mr. Liston reported that this group had considered the following items pertinent to the test program:

(1) Estimating payload for test purposes

(2) Estimating axle and track loads

(3) Considering the feasibility of testing at payloads in excess of design

(4) Estimating cost of additional tires and wheels if testing the wheeled vehicles with the same sized tires was desirable

The group had decided that although the weights of all three test beds were in excess of the target curb weight of 10,000 lb, the vehicles should be tested at the rated payload of 5,000 lb. It was also noted that the test beds could be tested at the target gross weight of 15,000 lb if such tests were desirable. For the approximate axle and track loads to be computed for the 5,000-lb payload, it was assumed that the load-carrying unit would be uniformly loaded if the following axle or track loads were used.

Unit	H.P./Ton	Load/Unit lb	Load/Axle or Track lb	Manufacturer's Recommended Inflation or Contact Pressure, psi	
				Off road*	On road**
			10x10		
Front	25.8	7600	3800	3	6
Rear		9800	3300	3	6
			8x8		
Front	22.5	3500	3500	3	6
Middle		10100	5050	3	6
Rear		5600	5600	3	6
			Track		
Front	22.4	8515	4258	2.32	2.32
Rear		10715	5358	2.41	2.41

* Maximum speed of 4 mph
** Maximum speed of 30 mph

The amount of overload permissible for operating on high strength soils was discussed. It was decided that the overload limit should not exceed 100% of the payload and that overload testing, if desired, should be deferred until after the manufacturer's warranty had expired. If it becomes necessary to test the wheeled test beds with a common tire size, additional tires and wheels can be purchased at an estimated cost of $900 per wheel. It was recommended that 10 wheels and tires be purchased to avoid tire switching during testing if such tests become desirable.

b. Site selection. Mr. Knight presented the report prepared by the site selection working group. He stated that the purpose of the group was to choose general test sites that were responsive to the test requirements established by the working group on test procedures. A primary consideration in the selection process was proximity of the test sites to Vicksburg, Mississippi, for reasons of economy and efficiency. An equally important factor was that the sites selected be the same general soil types (preferably CH) for technical reasons.

Based on the experience of personnel who have been engaged in mobility and environmental field testing over the last several years and on the results of reconnaissance made recently in the Mississippi River Delta area, the sites shown in table 5 were selected. Because both the accessibility and the soil strength at some of these sites vary with the season of the year, and particularly with river or reservoir stages, it was necessary to estimate those months of the year in which testing was feasible.

c. Schedule of testing. In a joint meeting of the test procedures and site selection working groups, a tentative schedule of testing was established as follows:

Time	Activity
14-26 Feb 67	Snow tests at Houghton, Mich. Begin purchase of instrumentation.
27 Feb - 13 Mar 67	Test beds en route to Vicksburg.
14 Mar - 15 May 67	Install instrumentation in test beds. Reconnaissance.
15 Apr - 10 May 67	Test first test bed and M113, M135, and XM410 on pavement, CI = 300 and CI = 80. Reconnaissance.
15-31 May 67	Test second and third test bed on pavement, CI = 300 and CI = 80. Reconnaissance.
1 Jun - 15 Jul 67	Test all vehicles: maneuver, drawbar pull - slip, motion resistance on CI = 300 and CI = 80. Reconnaissance.
15 Jul - 31 Aug 67	Test all vehicles: lateral obstacles and slipperiness. Reconnaissance.
1 Sep - ??	Test pertinent vehicles on CI = 5, 10, 20, and 40.

Attention was directed toward the frequent occurrence of the work "reconnaissance" in the above table. To ensure efficient and continuous operation of the whole test program, it will be necessary to conduct an almost continuous reconnaissance program to locate and stake out the required test locations before beginning the specific tests.

d. Test procedures. Mr. Rula reported the accomplishments of the test procedures working group. He stated that this group considered the agreed-upon objectives of each phase of the test program, outlined the kind of relations to be sought to meet the objectives, test conditions required for the various types of tests, size of test area required, and total number of tests required for each type of test, and prepared a list

of considerations for each type of test. The working group prepared a cost estimate for each phase of the test program and a tentative field testing schedule. All the above-mentioned material (Incl 3) was distributed to the attendees and sufficient time was allotted for them to review the contents.

24. Mr. Philippe concluded the meeting by expressing appreciation to all the participants for their efforts. He asked that no formal report be prepared on the meeting but that a document be prepared summarizing the proceedings. The approved minutes will be used to develop detailed test plans.

Table 1. Soil Strength (RCI) Ranges Required

Vehicle	Go - No Go VCI_{50}	Go - No Go VCI_1	Test Range VCI_{50}	Test Range VCI_1	Maneuver 1-Pass	Drawbar Pull 1-Pass
Experimental						
8x8 wheeled test bed	25	7	20-30	5-10	5-15	20-80
10x10 wheeled test bed	25	7	20-30	5-10	5-15	20-80
Articulated tracked test bed	25	7	20-30	5-10	5-15	20-80
Military						
M35 truck	57	28*	50-60	25-35	25-30	50-120
XM410 truck	34	17*	30-40	15-25	15-25	40-100
M113 personnel carrier	48	24*	45-55	20-30	20-30	50-120

* Assumed to be 50 percent of VCI_{50} for fine-grained soils.

Table 2. Location and Description of Suggested Test Areas

Location	Terrain Type	Test Period	6- to 12-in. RCI	Soil Type	Remarks
Vicinity of Vicksburg					
East of Miss. River	Floodplain pasturelands	Feb-Apr	40-150	ML,CL	
West of Miss. River	Floodplain pasturelands	Feb-Apr	60-150	CH	
Vicinity of Vicksburg	Marsh	Aug-Dec	5-60	CH	Large areas of uniform strength not available
Grenada Lake Grenada, Miss.	--	Oct-Dec	10-80	ML,CL	Backwater area
Louisiana Gulf Coast	Marsh	Aug-Feb	5-50	CH,OH,ML, Pt,CL	Watercraft will be required to obtain access to areas and in support of test program. Several locations will be required to obtain the strength range indicate

Table 3. Outline for Proposed WES Basic Test Plan

Soil-Vehicle Tests

Item No.	Purpose	Scope	Estimated No. of Tests	Estimated Costs
1	Determine experimentally the VCI for 1 and 50 passes	Conduct approximately 12 self-propelled tests with each vehicle at slow speeds in fine-grained soils at RCI range of 5-30	36	$ 46,400 (31,900)
2	Determine experimentally maximum speed vehicle can maintain at VCI_1	Conduct approximately 4 self-propelled tests with each vehicle at maximum maintainable speed in fine-grained soils at RCI range 5-15	12	7,400 (7,400)
3	Determine experimentally the minimum 1-pass soil strength required to maneuver	Conduct approximately 4 self-propelled tests with each vehicle at slow speeds in fine-grained soils at RCI range 5-15	9	7,400 (7,400)
4	Detemmine experimentally 1-pass drawbar pull-slip and drawbar pull, motion resistance-strength relations	Conduct drawbar pull-slip tests with each vehicle at slow wheel or track speed in fine-grained soils at three strength levels within 20-8- RCI range	9	37,000 (37,000)
			Subtotal	$ 98,200 (83,700)

Obstacle-Vehicle Tests

Item No.	Purpose	Scope	Estimated No. of Tests	Estimated Costs
1	Determine experimentally obstacle height negotiable	Conduct approximately 3 tests with each vehicle, starting with the front wheels or tracks in contact with the step height face. The step-shaped obstacle will be constructed on a firm surface. Passage will be at creep speed.	9	5,200 (3,700)

*Military vehicle test cost.

Table 3 (continued)

Item No.	Purpose	Scope	Estimated No. of tests	Estimated Costs
2	Determine experimentally fording depth	Conduct test in a concrete tank at approximately 4-ft water depth	9	$ 1,400 (1,400)*
			Subtotal	$ 6.600 (5,100)

Total Test Bed Vehicle Test Program Cost	$104,800
Total Military Vehicle Test Program Cost	88,800
Grand Total	$193,600

*Military vehicle test cost.

Note: Support costs do not include cost of water-borne equipment for testing on Gulf Coast islands.

Table 4. Outline of Proposed WES Supplemental Test Plan

Soil- or Pavement-Vehicle Tests

Item No.	Purpose	Scope	Estimated No. of Tests	Estimated Costs
1	Determine velocity, time-soil strength relations when accelerating or braking	Conduct about 3 tests with each vehicle in soils with CI strength range 10-15, 25-30, 50-60, 130-160, and 400-500.	72	$ 10,000 (10,000)*
2	Determine speed, maneuver-soil strength relations	The 6 vehicles will be tested on soils with a CI range of 10-20, 50-60, and 130-160, and at 7 speeds ranging from 2 to 30 mph	180	$ 20,000 (20,000)
3	Determine the effects of weak surface soil layers overlying firm soils on traction performance	Conduct tests with 6 vehicles on 2 soil types having two different mass soil strengths and a dry and a wet surface.	24	$ 4,100 (4,100)
4	Determine maximum force-speed relations on paved surface	Conduct tests with 6 vehicles in all gears at full throttle and at maximum velocity apply incremental loads until vehicle stalls	6	$ 2,000 (2,000)
			Subtotal	$ 36,100 (36,100)

Obstacle-Vehicle Tests

Item No.	Purpose	Scope	Estimated No. of Tests	Estimated Costs
1	Determine vehicle speed-obstacle height and energy required-obstacle height relations	Tests will be run with 6 vehicles over circular obstacles (logs) at heights of 4, 6, 8, 10, 12, 24, 28, and 30 in. with vehicle speeds ranging from 2 mph to the maximum speed the driver considers safe.	192	$ 15,000 (15,000)

* Military vehicle test cost

Table 4 (Continued)

Item No.	Purpose	Scope	Estimated No. of Tests	Estimated Costs
2	To determine the effects of obstacle spacing on vehicle maneuverability	Conduct tests with 6 vehicles in areas having approximately the same mass soil strength but 3 different obstacle spacings	36	$ 20,000 (20,000)*
			Subtotal	$ 35,000 (35,000)

Total test bed vehicle test program cost	$ 71,000
Total military vehicle test program cost	71,000
Grand total	$142,000

* Military vehicle test cost

Table 5. Site Selection

Rating Cone Index	No. of 20-Ft-Wide Lanes	Min. Length (Ft)	Dimensions* (Ft)	Probable Locations**	Suggested Location Priority***
			Quick and Dirty, and Refinements Phases (Except Maneuver Tests)		
5	18	300	360 x 300	1, 2	2(1), 1(2)
10	24	300	480 x 300	1, 2, 3, 4	2(1), 3(2), 4(3), 1(4)
20	35	400	700 x 400	1, 2, 3, 4	2(1), 3(2), 4(3), 1(4)
40	36	500	720 x 500	1, 2, 3, 4	2(1), 3(2), 4(3), 1(4)
80	36	1000	720 x 1000	4, 10	10(1), 4(2)
300+	3	5280	60 x 5280	5, 6, 7	6(1), 7(2), 5(3)
Pavement	1	5280	20 x 5280	6	6(1)
			Maneuver Tests (All 400 ft by 400 ft)		
10-15	3	--	1200 x 400	1, 2, 3, 4	Same as above
40	6	--	1200 x 800	1, 2, 3, 4	Same as above
300+	1	--	400 x 400	2, 8	2(1), 8(2)
			Relationships Phase		
--	--	--	--	10	--
			Verification Phase		
--	--	--	--	8, 9	--

NOTE: Locations with RCI's 5 through 40 available only from August to February.

* Smooth, level, fine-grained soils.
** Number is test location number.
*** Number in parentheses is test location priority.

List of Locations	Soil Type
1. Louisiana Gulf Coast	ML to CH
2. Centennial Lake	CH
3. Parker's Farm	CH
4. Grenada and Sardis Lakes	CL, ML
5. Ferris' Farm	ML, CL
6. Vicksburg and Jackson Airports	ML, CL
7. Old Airport, Vicksburg	ML, CL
8. WES reservation	ML, CL
9. Various military reservations	--
10. Vicksburg-Warren County areas	--

LIST OF ATTENDEES

Visitors

Mr. R. R. Philippe	U. S. Army Materiel Command
Mr. P. F. Carlton	U. S. Army Materiel Command
Mr. J. P. Sale	Office, Chief of Engineers
Mr. M. V. Kreipke	Office, Chief of Research and Development, Army Research Office
Mr. R. A. Liston	U. S. Army Tank-Automotive Command Land Locomotion Laboratory
Mr. C. J. Nuttall, Jr.	Wilson, Nuttall, Raimond, Engineers, Inc.
Mr. R. C. Kerr	Arlington, Va.
Mr. Bruce Rogers	Clark Equipment Co., Manager of Development Division
Mr. W. P. Gregory	Clark Equipment Co.

WES Personnel

*Col John R. Oswalt, Jr.	Director
*Mr. J. B. Tiffany	Technical Director

Soils Division

*Mr. A. A. Maxwell	Assistant Chief
Mr. R. G. Ahlvin	Chief, Flexible Pavement Branch

Mobility and Environmental Division

Mr. W. G. Shockley	Chief
Mr. S. J. Knight	Assistant Chief
Mr. A. A. Rula	Chief, Vehicle Studies Branch
Dr. D. R. Freitag	Chief, Mobility Research Branch
Mr. W. E. Grabau	Chief, Terrain Analysis Branch
Mr. E. S. Rush	Chief, Soil-Vehicle Studies Section, Vehicle Studies Branch
Mr. J. K. Stoll	Chief, Obstacle-Vehicle Studies Section, Vehicle Studies Branch
Mr. B. G. Stinson	Obstacle-Vehicle Studies Section, Vehicle Studies Branch
Mr. A. J. Green	Chief, Vehicle Dynamics Section, Mobility Research Branch
Mr. J. L. Smith	Chief, Mobility Fundamentals Section, Mobility Research Branch
Mr. B. O. Benn	Chief, Data Development Section, Mobility Research Branch

* Attended initial meeting

Incl 1

Agenda

Planning Conference for Preparing a Field Testing
Program for Vicksburg Exercise A Vehicles

Vicksburg, Mississippi

8-10 February 1967

General Chairman - Mr. R. R. Philippe

8 February

0915	Purpose of Meeting, Funding and Official Guidelines	R. R. Philippe
0930	Resume of Vicksburg Exercise A	W. G. Shockley
1000	Coffee Break	
1030	Design, Fabrication, and Status of Vehicle Test Beds	Representative, Clark Equip. Co.
1100	Discussion	
1150	Lunch	
1300	A Proposed Basic Plan for Testing Vehicle Test Beds	A. A. Rula
1330	A Proposed Supplemental Plan for Testing Vehicle Test Beds	B. G. Stinson
1415	Discussion	
1445	Coffee Break	
1515	Assignment of Working Groups to Review, Modify, or Develop Acceptable Test Plan	
1600	Adjourn	

9 February

0900	Working Groups Convene	
1230	Lunch	
1330	General Meeting to Coordinate Accomplishments of Working Groups	
1600	Adjourn	

10 February

0900	Working Groups Convene	
1000	Assembly of Working Groups to Agree on Plan of Tests	
1130	Summary	R. R. Philippe
1200	Adjourn	

Incl 2

Test Procedures

Phase I:

The objective of Phase I is to establish the relation between soil strength and cargo delivery (in ton-miles/hr) for the entire spectrum of soil strengths, from the immobilization point of each test bed and test vehicle to a hard-surface road. An essential condition is that no terrain factors other than soil strength will be considered.

Soil Strength Versus Speed Relation Tests

Vehicle	VCI*	Soil Strength, RCI 5	10	20	40	80	300+	Pavement
		Test Lane Lengths Required						
		300 ft	300 ft	400 ft	500 ft	1000 ft	5000 ft	5000 ft
AMC Test Beds								
8x8	10*	X	X	X	X	X	X	X
10x10	8*	X	X	X	X	X	X	X
Tracked	14*		X	X	X	X	X	X
Standard Military Vehicles								
M35	28**			X	X	X	X	X
XM410	17**		X	X	X	X	X	X
M113	24**			X	X	X	X	X
Number of test lanes required		10†	20	30	30	30	3	1
				Total number of test lanes				124

* Estimated by WES numeric
** 50% of 50-pass VCI (VCI_{50})
† Five tests are programmed for each vehicle; however, if three tests yield closely similar performance values, three tests will be accepted as adequate

Incl 3

Considerations:

1. All vehicles will be loaded to rated weight.

2. All test lanes will be on fine-grained (preferably clay) soils.

3. All test lanes will be smooth, horizontal, and with RCI values as uniform as possible.

4. Test design is premised on essentially uniform soil strength with depth.

5. All tests will be conducted with the vehicle starting from a dead stop. Each machine will be accelerated at maximum rate to the maximum sustainable speed; this speed will be maintained through a fixed distance; at the conclusion of the constant-speed run, the power train will be disengaged and the vehicle permitted to roll to a stop.

6. Vehicles will be instrumented to continuously record drive-line torque, distance traveled by vehicle, distance traveled by fixed point on periphery of wheel or track, time, longitudinal and vertical acceleration in driver's compartment, and engine rpm.

7. Each test lane will be described prior to testing by an appropriate array of RCI, shear stress, and normal stress relations. Soil adhesion and stress-strain properties of the soil at the normal stress imposed by the vehicle will be measured. Soil samples will be taken for laboratory analysis.

8. Post-test data will include detailed profiles of each track.

Phase II:

The objectives of Phase II are to establish the engineering performance characteristics of the test beds and test vehicles, in conjunction with Phase I over the full strength range of soils, and to determine essential terrain-vehicle relations, including acceleration and deceleration, maneuverability, drawbar slip relations, motion resistance, and VCI on soft soil conditions.

<u>Maneuver Tests</u>

<u>400- x 400-ft Test Areas Required</u>

Vehicle	VCI_1	Soil Strength, RCI					
		10-15	20	40	80	300+	Pavement
				AMC Test Beds			
8x8	10	X		X		X	
10x10	8	X		X		X	
Tracked	14	X		X		X	
				Standard Military Vehicles			
M35				X		X	
XM410				X		X	
M113 (2-1/2-ton load)				X		X	
Number of test lanes required		3*		6		1	

Total number of test lanes required 10

* Five tests are programmed for each vehicle; however, if three tests yield closely similar performance values, three tests will be accepted as adequate.

Considerations:

1. Test areas will consist of smooth, horizontal surfaces exhibiting RCI values as uniform as possible.

2. Soils will be fine-grained.

3. Vehicles will be tested at full rated load.

4. Each vehicle or test bed will be tested at a spectrum of speeds, from a minimum of 2 mph to a maximum of 30 mph or the maximum sustainable speed, whichever is less.

5. The test machine will enter the test area at prescribed speed, and at a given point will be turned at the maximum steering response rate unless skidding occurs, at which point the steering angle will be reduced sufficiently to avoid skidding.

6. The soil conditions in each test lane will be adequately characterized by measurements of cone index, remolding index, and sheargraph data consisting of shear stress at the normal stress equal to the vehicle contact pressure and adhesion. Bulk soil samples will be obtained at each test location for the determination of Atterberg limits and grain size analysis for soil classification purposes.

7. Post-test data will include planimetric maps of wheel tracks and swept areas. Detailed profiles of each wheel or track rut will be taken.

Drawbar Pull, Slip, Motion Resistance Tests

(100- to 200-ft-long test lanes required)

Vehicle	VCI_1	Soil Strength, RCI 10-15	20	40	80	120	300+	Pavement
AMC Test Beds								
8x8	10*		X	X	X			
10x10	8*		X	X	X			
Tracked	14*		X	X	X			
Standard Military Vehicles								
M35				X	X	X		
XM410				X	X	X		
M113				X	X	X		
Number of test lanes required			3	6	6	3		

Total number of lanes 18

* Estimated by WES numeric

Considerations:

1. Test lanes will be smooth, horizontal, and characterized by RCI values as uniform as possible.

2. Soils will be fine grained.

3. Vehicles will be tested at full rated load.

4. Vehicle track or wheel speed will be maintained at approximately 2 mph.

5. Test instrumentation will consist of drive-line torque, distance traveled by vehicle, drive-shaft revolutions, time, distance traveled by fixed point on perimeter of wheel or track, longitudinal acceleration, and drawbar pull (for drawbar-pull tests only).

5. Soil conditions in each test lane will be adequately characterized by measurements of cone index, remolding index, and sheargraph data consisting of shear stress at the normal stress equal to the vehicle contact pressure and adhesion. Bulk soil samples will be obtained at each test location for the determination of Atterberg limits and grain-size analysis for soil classification purposes.

6. Drawbar-pull tests will be conducted according to standard practices.

Towed Motion Resistance Tests

(100-ft long test course required)

Vehicle	RCI_1	Soil Strength, RCI 10-15	20	40	80	120	300+	Pavement
AMC Test Beds								
8x8	10*		X	X	X			
10x10	8*		X	X	X			
Tracked	14*		X	X	X			
Standard Military Vehicles								
M35				X	X	X		
XM410				X	X	X		
M113				X	X	X		
Number of test lanes required			3	6	6	3		

Total number of test lanes 18

* Estimated from WES numeric

Considerations:

1. Test lanes will be as discussed for drawbar-pull tests.

2. Test-lane soils data will be taken as described for maneuver tests.

3. Continuous measurements of distance traveled by the vehicle, time, drive-shaft revolutions, wheel or track speed, and towing force will be obtained.

4. Test speeds will be maintained at 2 mph for all tests.

5. Post-test data will include detailed profiles of each wheel or track rut.

Vehicle Cone Index Tests

(100-ft-long test lanes required)

Vehicle	VCI_1	VCI_{50}	Soil Strength: Test Range VCI_1	Soil Strength: Test Range VCI_{50}	Soil Strength: No. of Lanes VCI_1	Soil Strength: No. of Lanes VCI_{50}
AMC Test Beds						
8x8	10*	25	20-30	5-10	4	4
10x10	8*	25	20-30	5-10	4	4
Tracked	14*	25	20-30	5-10	4	4
Military Vehicles						
M35	28**	57	25-35	50-60	4	4
XM410	17**	34	15-25	30-40	4	4
M113	24**	48	20-30	45-55	4	4
			Total number of tests		24	24

* Determined from WES numeric
** 50 percent VCI_{50}

Considerations:

1. Test lanes will be smooth, horizontal, and characterized by RCI values as uniform as possible.

2. Soils will be fine grained.

3. Vehicles will be tested at full rated load.

4. Vehicle track or wheel speed will be maintained at approximately 2 mph.

5. Test instrumentation will consist of drive-line torque and distance traveled by fixed point on perimeter of wheel or track.

6. The soil conditions in each test lane will be adequately characterized by measurements of cone index, remolding index, and sheargraph data consisting of shear stress at the normal stress equal to the vehicle contact pressure, and adhesion. Bulk soil samples will be obtained for laboratory analysis.

Phase III:

The objectives of Phase III are to refine or improve those terrain-vehicle relations which can be predicted or described with the least reliability by the existing cross-country speed performance model, with special emphasis on the dynamic responses of the machines to vertical obstacles (i.e., ground roughness), and soil slipperiness-traction relations. An ancillary objective is to update the cross-country speed prediction model.

Vertical Obstacles

Tests will be performed on a prepared course designed to provide empirical relations which can be used to evaluate immediately the test vehicles on a comparative basis as well as to furnish a precise record of the time displacement history of the axle from which analytical refinements may be made to the existing model for predicting dynamic response, speed, and energy requirements.

The approach proposed for the general objective of the study of vehicle performance in vertical obstacles is divided into three stages, each of the latter a logical outgrowth of its predecessor. Stage I will consist of conducting tests and deriving empirical relations. The empirical relations are those of (a) maxima of longitudinal and vertical acceleration versus speed for various ranges of obstacle severity and (b) work (lb-ft) versus vehicle speed at contact with obstacle for various ranges of obstacle severity.

Tentative Schedule for Vertical Obstacle Tests - Stage I

Vehicle	Obstacle Shape* Trapezoidal	Obstacle Shape* Circular	Obstacle Approach Angle (Acute) Deg.	Obstacle Height in.
			Dynamic Tests (>2 mph)	
M35A1		X	NA	8,10,12,16
	X		20,30,45,90	8,10,12,16
M113		X	NA	8,10,12,16
	X		20,30,45,90	8,10,12,16
XM410		X	NA	4,8,10,12,16
8x8 Wheeled Concept	X		20,30,45,90	4,8,10,12,16
		X	NA	4,8,10,12,16
10x10 Wheeled Concept	X		20,30,45,90	4,8,10,12,16
		X	NA	4,8,10,12,16
	X		20,30,45,90	4,8,10,12,16
Tracked Concept		X	NA	4,8,10,12,16
	X		20,30,45,90	4,8,10,12,16
			Static Tests (≤2 mph)	
M35A1		X	NA	18,20,22
	X		Variable between 38 and 31	Variable from min. to 90
M113		X	NA	20,24,26,28
	X		Variable between 69 and 31	Variable from 80 to min.

Tentative Schedule for Vertical Obstacle Tests - Stage I (Cont'd)

Vehicle	Obstacle Shape*		Obstacle Approach Angle (Acute) Deg.	Obstacle Height in.
	Trapezoidal	Circular		
XM410		X	NA	
	X		Variable between 48 and 31	Variable from 100 to min.
8x8 Wheeled Concept		X	NA	20,22
	X		Variable between 90 and 35	Variable between 100 and min.
10x10 Wheeled Concept		X	NA	$\geq$Undercarriage Clearance
	X		Variable between 67 and 35	Variable between 100 and min.
Tracked Concept		X	NA	16,18,24,32,38
	X		Variable between 75 and 35	Variable between 100 and min.

* Previous testing by WES using shapes ranging from circular to polygonal with approach angles of 30, 45, and 90 degrees has indicated obstacle shape did not significantly influence the dynamic response of several conventional military vehicles. Provided this holds true for the above-listed vehicles in early tests, the trapezoidal shapes will be eliminated in subsequent tests.

Considerations:

1. The most precise means available for measuring time displacement of the axles and body center of gravity and accelerations on the vehicle will be implemented.

2. Considerable care will be exercised in determining the physical properties of each test vehicle which are required as input to the mathematical model.

3. Tests will be conducted with vehicles loaded to their rated capacities.

4. A trained driver will be used in conduct of tests.

5. The obstacle geometry and spacing will be precisely measured and described in a format acceptable for computer analysis.

6. The level surface on which the obstacles are placed should be dry and firm enough to prevent rutting or transient deformation. The exact condition of the traction surface will be quantitatively described for the purpose of predicting the maximum tractive force required to surmount the obstacles.

7. Obstacles should be securely anchored to give them complete rigidity.

8. At least two and preferabl· three repetitions will be completed for each vehicle and obstacle geometry test condition.

Stage II will consist of linking together the existing FMC mathematical model for predicting dynamic response on hard, irregular surfaces and the WES technique for modeling the dynamic performance of tires. These two prediction models will be used to predict vehicle response to the obstacles used in the tests in Stage I. The final stage (Stage III) in the development

of a realistic model for predicting vehicle performance over vertical obstacles in the cross-country context requires that the part of the model representing the terrain be refined to include the effects of deformable obstacles--for the most part, soil. The spring and damping properties of the soil can be empirically determined by a series of vehicle tests on deformable obstacles using the mathematical model developed in Stage II for control. From this series of tests the empirical values obtained should be related to measured soil properties.

Performance Evaluation in Lateral Obstacles

The principal purpose for conducting the lateral obstacle tests is to evaluate and compare by quantitative methods the speed at which the test beds and three military vehicles of similar configuration and payload capacity can maneuver through various spacings of lateral obstacles. A secondary purpose is to compare test results with performance curves of speed versus mean obstacle spacing computed by analytical methods.

Schedule of Lateral Obstacle Tests

No. of Vehicles*	Soil Mass Strength (CI)	Average Obstacle Spacing	No. of Tests per Vehicle	Total No. of Tests
6	>100 for 0- to 6-in. Layer	15 ft	2	12
		25 ft	2	12
		40 ft	2	12
		Total number of tests required		36

* Test vehicles: M35, XM410, M113, 8x8 wheeled test bed, 10x10 wheeled test bed, and tracked test bed.

Considerations:

1. Vehicles will be tested at the rated load capacity.

2. Three test sites approximately 200 by 500 ft will be selected, each with a specific obstacle spacing and a smooth, level ground surface.

3. Soil strength will not be considered as a variable.

4. A trained driver will be used in the conduct of tests. He will be instructed to drive at a safe maximum speed.

5. Adequate data will be taken to describe the test courses in terms of soil properties, surface irregularities, and obstacle spacing.

6. Understory vegetation will be cleared to eliminate visibility as a factor.

7. During test runs, drive-line torque, drive shaft revolutions, wheel or track speed, time, and ground position reference pips will be recorded.

Performance Evaluation in Longitudinal Obstacles

Previous testing by WES has resulted in an adequate definition of maximum horizontal pushbar force, i.e. longitudinal force required to override vegetation as a function of stem diameter and pushbar height (see fig. 1). A detailed explanation of the derivation of these relations is given in "An Analytical Model for Predicting Cross-Country Vehicle Performance, Appendix B: Vehicle Performance in Lateral and Longitudinal Obstacles" (unpublished).

From fig. 1 it may be seen that the lines defining maximum horizontal pushbar force for 20-in. pushbar height and 38-in. pushbar height are

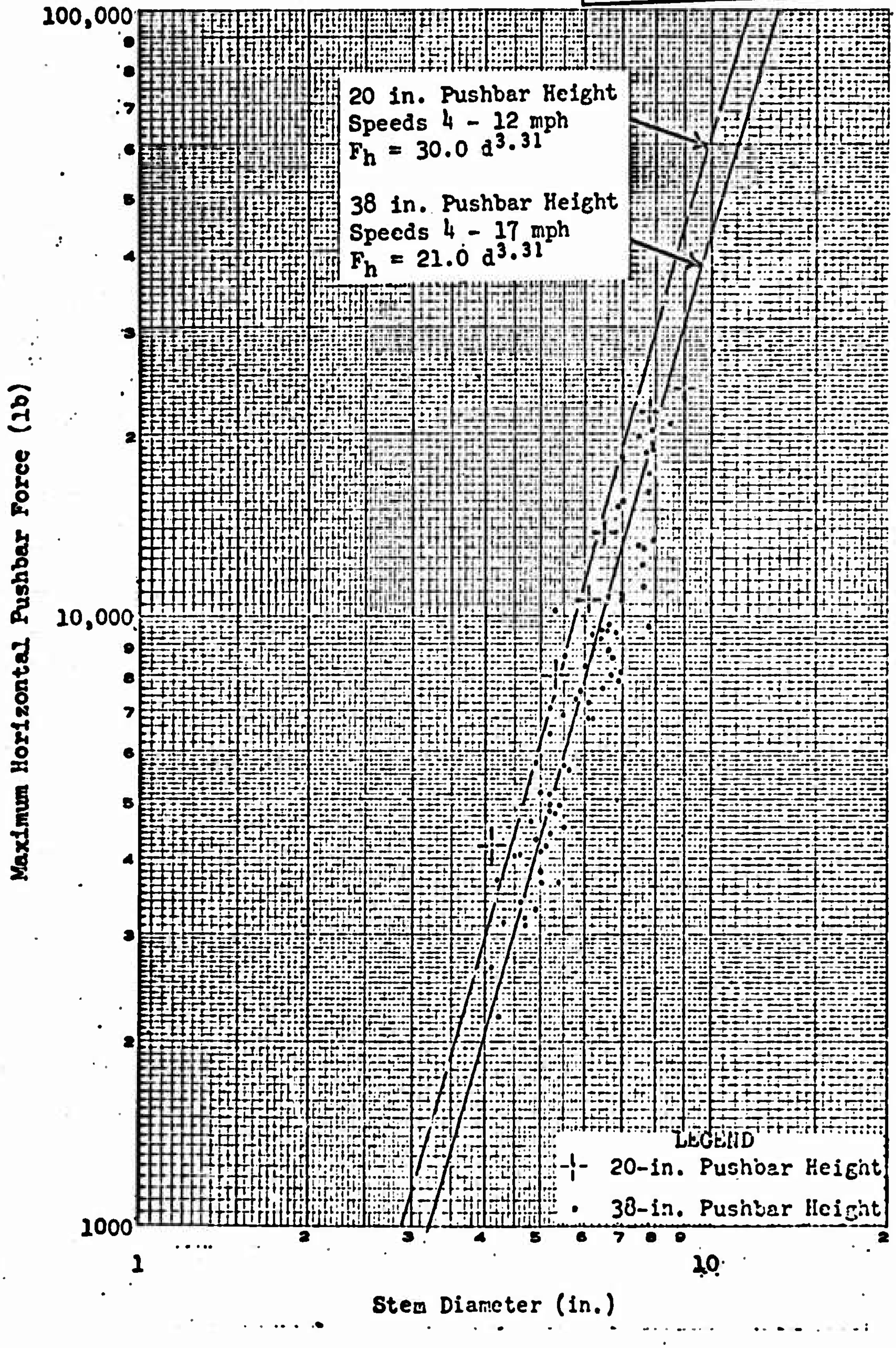


Fig. 1. Stem Diameter Versus Maximum Horizontal Pushbar Force for Speeds Greater than 4 Miles per Hour

parallel and the two equations may be combined into a general equation for any pushbar height within the 20- to 38-in. range as follows:

$$F_h = [30 - 0.5\,(H_p - 20)]\,d^{3.31}$$

wherein:

F_h = maximum horizontal pushbar force, lb

H_p = pushbar height, in.

d = stem diameter, in.

With this relation well established there appears little to gain by conducting tree override tests with the prototype vehicles; however, there are two limits which are not included in the formula that must be established.

The first of these is the structural stress limit of the vehicle, or more specifically, the maximum dynamic force the leading edge of the vehicle can sustain without damage. This force, to be supplied by the manufacturer, can be inserted along with the height of the leading edge into the general equation and the equation solved for the maximum stem diameter that may be overridden.

The other limit is the impact the driver can tolerate. Experience has shown that the tolerable limit of acceleration in a longitudinal direction for the driver is in the range of 1.5 to 2.0 g. By restating the general equation in terms of acceleration, the stem diameter that forms the driver's limit is found.

$$a = \frac{[30 - 0.5(H_p - 20)]\,d^{3.31}}{w}$$

wherein:

a = acceleration, g

w = weight of vehicle, lb

Subject to these limitations, the equation describes force required to override a longitudinal obstacle at speeds greater than 4 mph.

Effects of Wet-Surface Soil Condition on Traction Performance

Both laboratory and field tests have demonstrated that a thin film of water or weak soil over a relatively firm soil will reduce drastically the maximum drawbar-pull capabilities of vehicles. Recent testing has placed emphasis on the development of a suitable means for measuring the soil properties that can be related to surface-traction performance.

The purpose of these tests is to determine effects of surface soil layers with low shear strength overlying firm soils on traction performance of each vehicle.

Tractive force-slip and drawbar pull-slip tests will be performed on firm, natural soil conditions, first on a relatively dry surface and next on the same surface after wetting. Each of the six vehicles will be tested on two soil types (silt and clay) at three different strengths each. A minimum of six tests per vehicle will be required.

Schedule of Tests

No. of Vehicles*	Soil Type	Soil Shear Strength** (psi)	No. of Tests: Constant Velocity 3 ft/sec	No. of Tests: Acceleration Zero to Max. Velocity***
6	Clay (CH)	Firm, dry, natural soil surface	6	6
		4-5	6	6
		1-2	6	6
	Silt (ML-CL)	Firm, dry, natural soil surface	6	6
		4-5	6	6
		1-2	6	6
		Totals	36	36

* M35A1, XM410, M113, 8x8 wheeled test bed, 10x10 wheeled test bed, and tracked test bed

** As expressed in the Coulomb equation, $S = C + P \tan \phi$

*** These tests will be conducted only if time and money are available.

Considerations:

1. Vehicles will be tested at their rated load capacity.

2. Test sites are to be selected on smooth, level areas barren of vegetation.

3. Test lanes should be 100 to 200 ft in length for the constant speed tests and 1000 ft in length for the acceleration tests.

4. Drive-line torque, drawbar pull, drive shaft revolutions, wheel or track speed, distance, longitudinal acceleration, and time will be measured during the conduct of the tests.

5. Soil shear strength will be measured with the cone penetrometer and Cohron sheargraph in each wheel or track path prior to testing.

6. Moisture content samples of the near-surface layer will be taken.

7. Bulk samples will be taken for grain-size analysis and determination of Atterberg limits.

8. The tests require an experienced vehicle test driver.

Phase IV:

The objective of Phase IV is to test the capability of the updated cross-country speed prediction model to reliably predict the cross-country speed performance of the test beds and test vehicles. This phase will incorporate an evaluation of the possible degradation of prediction accuracy as a result of terrain input derived by air-photo interpretation as opposed to field measurement of appropriate terrain parameters.

This phase of the problem was not given any special consideration because the inputs from the other three phases are required before reliable test procedures can be established.

ESTIMATED COSTS

Phase		Testing and Data Collection	Instrumentation	Data Analysis	Total
I	WES	$ 80,000	$15,000	$ 5,000	$100,000
	LLL	13,000	5,000	2,000	20,000
II	WES	85,000	10,000	20,000	115,000
	LLL	25,000	5,000	10,000	40,000
III	WES	112,000	0	*	112,000
	LLL	15,000	0	*	15,000
IV	WES	30,000	0	*	30,000
	LLL	15,000	0	*	15,000
Subtotal		$375,000	$35,000	$37,000	$447,000

*In-house funds to be used.

Tentative Field Testing Schedule

Test Program	1967 F	M	A	M	J	J	A	S	O	N	D	1968 J	F
Part I		----	----	----	----	----			----	----	----		
Part II		----	----	----	----	----			----	----	----		
Part III						----	----	----					
Part IV								----	----				